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FROM HEAD OF DEPARTMENT

PROFESSOR M. L. G. REDHEAD

24.10.90

Dear Richard,

Thank you for your letter dated 10th October. The beginning of term has been quite hectic, so apologies for not replying earlier! I liked the distinctions you drew on p.3 between different possible versions of PII. But, turning to p.11 ff., I do have some critical comments.

1) The molecules of a gas are no more distinguishable than fundamental particles like electrons or protons.

2) It is wrong to say (p.12) that molecular gases obey Maxwell-Boltzmann statistics. They obey quantum statistics of one or other variety. At low pressures and/or high temperatures the same thermodynamic predictions as M-B statistics. Under these conditions very few one-particle states will contain more than one particle, so M-B counting is the same as B-E, or F-D counting. On the other hand, at high pressures and/or low temperatures, all gases exhibit clear

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is called degeneracy, i.e. departure from M-B statistics, since it is the probabilistic weights attaching to multiply-occupied states that distinguishes the three sorts of statistics.

For a very clear discussion see Max Born: Atomic Physics, published by Blackie and Son. (see p. 230 ff. in the 8th edition, 1969).

3) At the end of p. 12 you say "distinguishability is a matter of there being a truth — this is not how "distinguishable" is used in physics. Here it means "there exists an observation, which could enable us to tell which was which", so the mere possession of thirteen does not make entities distinguishable. In fact, in first-quantized versions of quantum theory the particles are given labels and so are assumed to have thisness. The quantum statistics come out as a result of restrictions on accessible states, in the way spelled out in my paper with French.

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II

4.) There is a quite different way of dealing with indistinguishable particles in quantum theory from as second quantization. Here the particles are not given labels but are regarded as excitations of a quantum field. In this approach the particles do not have thisness and B-E statistics is easy to accommodate, but F-D statistics, while it can be done mathematically in a second-quantized approach, is difficult to explain in an intuitive way, since the fermion field amplitude is not itself an observable!

5.) There remains the question: How do macroscopic objects become distinguishable (a) In the second-quantized approach this happens when the associated field excitations do not overlap spatially, so a notion of distinct trajectory

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can be treated, which is not in general the case for systems of electrons or molecules.

(2) In the first-quantized approach the problem is much more difficult. Every electron in my body is entangled by antisymmetrization with every electron in your body! It is quite similar to other cases of entanglement in quantum mechanics, like Schrödinger's cat. Somehow, but nobody agrees exactly how, entangled states must project out, in macroscopic objects, so that my electrons are really mine and not yours also, if I can put it like that.

I hope these remarks are of some use to you.

With my best wishes

Michael